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Radiological Toolbox User's Manual

December 31, 2003

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ABSTRACT

A database of radiological data has been assembled to provide users access through a single interface to the physical, chemical, anatomical, physiological and mathematical data of relevance to the radiation protection of man. The database and associated software is referred to as a toolbox. The software provides users with quick access to the data and the means to extract data for further computations and analysis. The numerical data, for the most part, are stored within databases in SI units however the user can display and extract values using non SI units. This is the first release of the toolbox developed for the Nuclear Regulatory Commission.

1. INTRODUCTION

The Radiological Toolbox (Rad Toolbox) was developed for the U.S. Nuclear Regulatory Commission (NRC). This computer application provides users access through a single GUI (graphical user interface) to a variety of physical, chemical, anatomical, physiological and mathematical (and models) data relevance to the radiation protection of man. The interface enables viewing of the data and also provides a means to extract data for further computations and analysis. The numerical data, for the most part, are stored in SI units however the user can display and extract the data using non SI units. The data are stored in MicroSoft Access databases and in flat ASCII files. This is the first release of the toolbox. The following data elements are included:

- Absorber data for elements and materials
  - Alpha range and stopping power data
  - Electron range and stopping power data
  - Photon interaction cross-sections
  - Neutron and photon kerma
- Biological data
  - Biokinetic models
  - Organ masses
  - Dietary and respiratory intake rates
- Nuclear decay data
  - ICRP Publication 38
  - JAERI compilation
- Dose coefficients (Nuclide-specific)
  - Radionuclide intake
    - Radiation workers - ICRP Publications 30 and 68
    - Member of the public – ICRP Publication 72
  - External irradiation – Federal Guidance Report 13
    - Submersion, immersion, ground plane, and soil
- Inhalation absorbed dose coefficients for deterministic effects
  - User-specified integration times
- Element data
  - Abundances, atomic masses, and general information
- Material data
  - Elemental composition of common materials
  - Isotropic composition of elements
- Public exposure data
  - Natural background radiation doses
  - Concentration data for natural occurring radioisotopes
- Dose Coefficients for photon and neutron fields – ICRP Publication 74
  - Operational quantities
  - Organ doses for 6 exposure geometries
- Supplemental data – conversion factors, etc.

For the most part the software simply accesses the databases and converts the requested values to the units specified by the users. However, computational modules are used to calculate the inhalation dose coefficients for deterministic effects for the time period specified by the user and to compute the interaction coefficients for materials from their elemental composition. The latter are simply a linear combination of the elemental data however in the case of photons one must interpolate the data at the energies associated with the K- and L-edges. The software's help files provide ready access to textual information. Help is currently available on a broad range of topics ranging from a general nature (General menu item) to the details of the models of describing the fate of elements that have been absorbed in the body.

1.1 Release Notes

This is the first general release of the toolbox. All bugs found during the beta testing period have been addressed and most of the enhancements suggested in the beta review process have been included.

1.1.1 Installing the software

The toolbox is installed by running the SETUP.EXE module on the distribution CD. It is suggested that the software be installed into the default folder. During the installation the system may report several messages for which the 'ignore' option is the appropriate response. The installation will place a 'shortcut' on the 'desktop' with a toolbox-like icon. Clicking on the shortcut will invoke the software to display the initial screen of Fig. 1. The software can be removed from the computer by running UNINS000.EXE in the folder containing the software; *Program Files\rad_tool* if the default folder was used.

1.1.2 Known bugs in version 1.0

There are two known "bugs" in this release:

a. In some instances, the graphical display of the decay chain associated with the parent radionuclide may contain artifacts; e.g., see the Am-242m chain. However the software should not crash as the chain is assembled. Needless to say, the decay chain graphics has not been tested for all of potential parent nuclides.

b. Within the dose coefficient folder the identity of a requested nuclide is retained as one goes from one type of coefficient to the next. If the requested nuclide does not exist in a subsequent coefficient type then a message box appears stating "no nuclides found" - the correct response. However when the "OK" button on the message box is click an empty display screen appears – form which clicking "OK" returns to the appropriate display. This "bug" can be demonstrated by going to "Dose Coefficient" section, selecting the "Public External Coefficient" folder and display the coefficient for Rn-222. After displaying the coefficients then pick any folder addressing radionuclide intake (e.g., Worker Coefficients (ICRP 30)). Note that the requested nuclide is still Rn-222. However if one attempts to display the coefficients the message box noted above appears. This occurs since dose coefficients for intake of noble gas radionuclide was not addressed (neither were radionuclides of half-life less than 10 minutes but they were for external irradiation) however future version of the software will provide a more appropriate response.

1.2 Support

If you encounter any problems running the Rad Toolbox, please contact Andrea Sjoreen (sjoreenal@ornl.gov or 865-574-5333) at Oak Ridge National Laboratory. If you have questions or comments of a technical nature, please contact Keith Eckerman (eckermankf@ornl.gov or 865-574-6251) at Oak Ridge National Laboratory. Comments on style, usability, and other features that could be included would be appreciated.

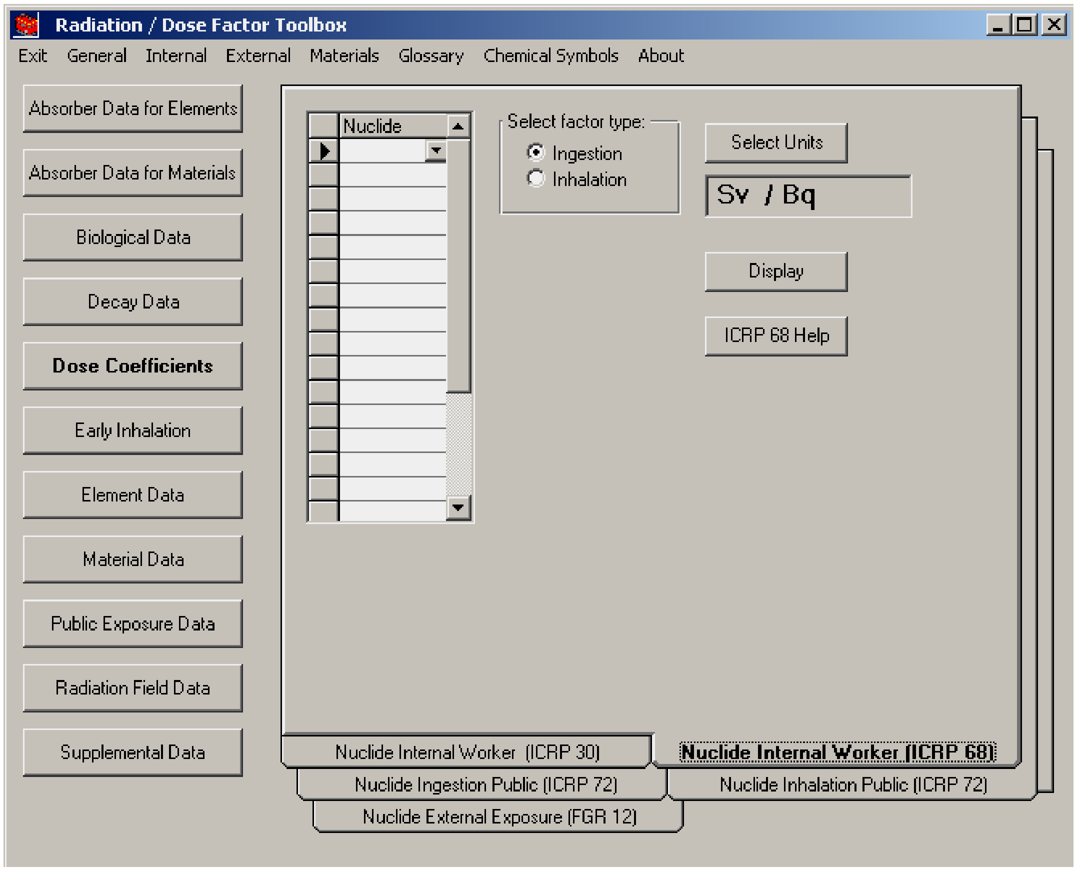

Fig. 1. Rad Toolbox initial screen at startup. The column of buttons on the left provide different access to data within the 'folders' appearing on the right.

2 TOOLBOX CONTENT

When the toolbox is invoked the screen of Fig. 1 appears. In the discussion below the column of buttons on the left are said to refer to different *sections* of the toolbox while the structure on the right is referred to as *folders*. Note these terms to not refer to the database structures but only facilitate the discussion here. It may be helpful to consult Fig. 1 in the following sections which bear the name of the buttons of Fig. 1.

2.1 Absorber Data

The Absorber Data section of the toolbox provides access to interaction coefficients for alpha, electron, photon and neutron radiations by element or material (see Fig. 2). The user may select the type of data (coefficient) for display and its units. From the table is displayed the data may be plotted, as a function of energy, by double-clicking on the data column of interest. The entire table may be exported to Excel. Coefficients are not are available for all every element for each radiation type. The kerma coefficients were taken from KERMAL, RSICC package DLC-143 (Howerton, 1986a and 1986b). All other data are from Hubbell and Seltzer (1997) and Berger et al. (1999).

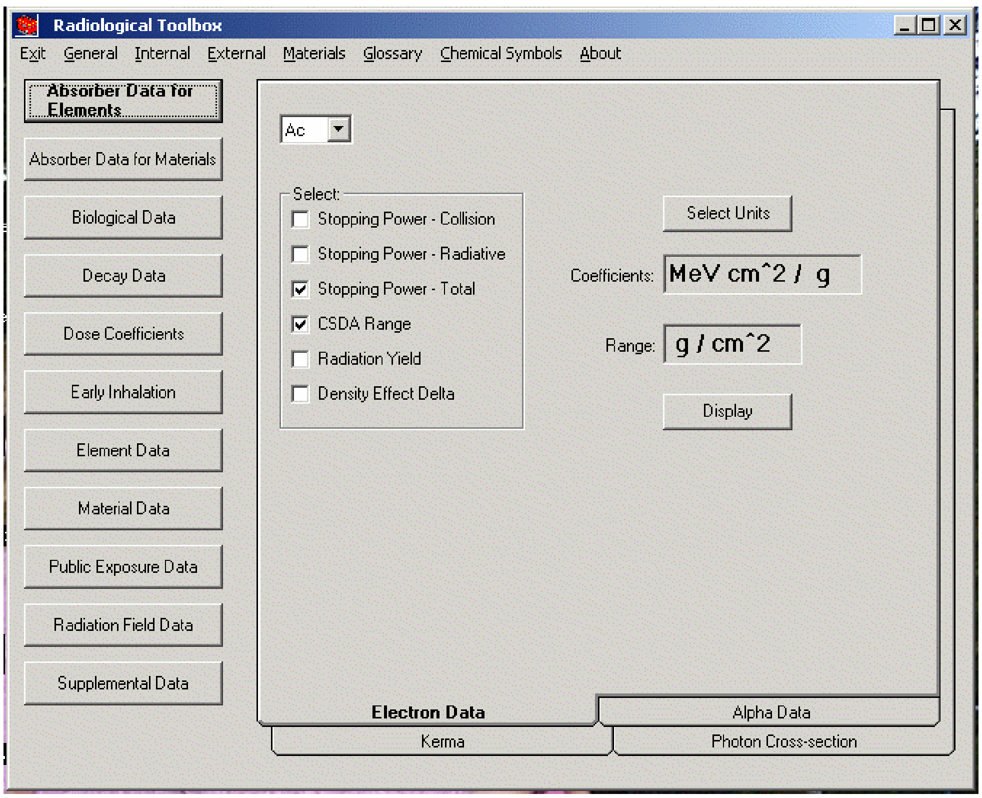

Fig. 2. The screen display for entrance into the absorber data.

Photon cross section data are for the following processes:

- scattering - coherent
- scattering - incoherent
- photoelectric absorption
- pair production in a nuclear field
- pair production in an electron field

total attenuation with coherent scattering
total attenuation without coherent scattering
mass energy-absorption coefficients.

The electron interaction coefficients include:

stopping power - collision
stopping power - radiative
stopping power – total
continuous slowing dose approximation (CSDA) range
radiation yield
density effect delta.

The alpha data available are:

electronic stopping power
nuclear stopping power
total stopping poser
continuous slowing dose approximation (CSDA) range.

Kerma coefficients are provided for

photons
neutrons.

The photon mass energy-absorption coefficients were tabulated at fewer photon energies than the other interaction coefficients. The values of the mass energy-absorption coefficients at the additional energies were obtained by log-log interpolation. The interpolated values appear in the displayed tables with a colored background.

Interaction and kerma coefficients for various materials were derived for the material of compositions specified in the Material Data section (Coursey et al., 2001). See Fig. 3. Thus the material definitions in the Howerton (1986a, 1986b) references were not used. Since kerma data were only available for atomic numbers less than 30, only materials composed of these elements could be considered. In computing the coefficients for neutrons, the isotopes of the composition were assumed to either the natural isotope or the most abundant isotope of the element.

2.2 Biological Data

The Biological Data section (see Fig. 4) of the toolbox contains data on the following:

biokinetic models
composition of tissues
organ masses
food intake rates
inhalation rates
threshold and lethal doses

These data are displayed in tables many of which can be exported to Excel. The biokinetic models are from ICRP Publication 68 (ICRP 1994) and Publication 72 (ICRP 1997a). The data on the composition of tissues can be sorted by atomic number or fraction. The organ masses are from ICRP Publication 72 (ICRP 1997a). The compositions of tissues are from Coursey et al (2001). The inhalation rates are from ICRP Publication 68 (1994) and ICRP Publication 72 (1997a). The food intake rates are from Eckerman, et al (1999). The threshold and lethal doses are from Abrahamson et al. (1989). See also the EPA's manual on PAGs (EPA, 1992).

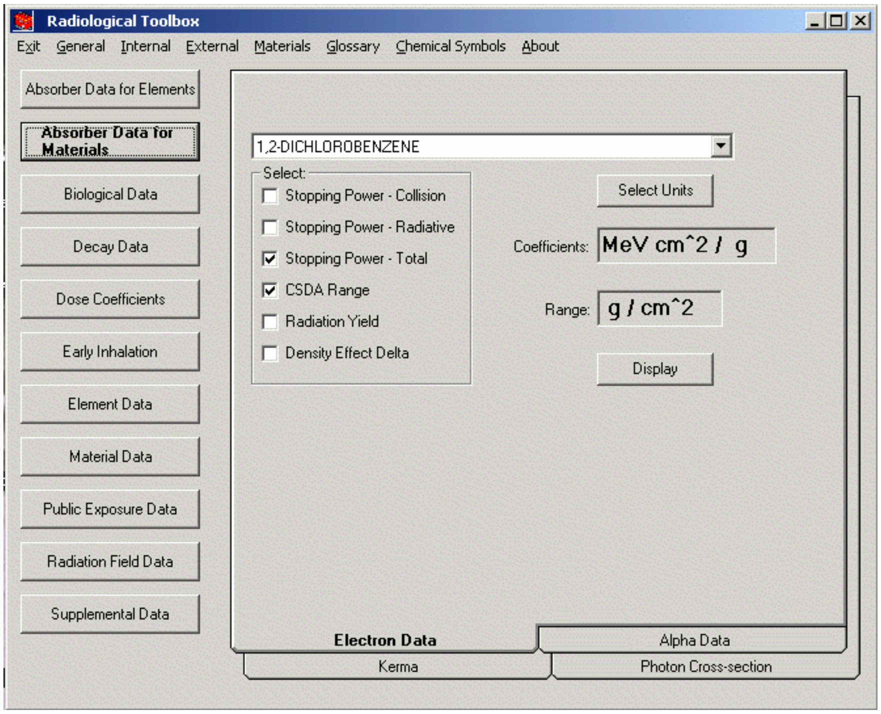

Fig.3. The screen display for entrance into the absorber data for materials.

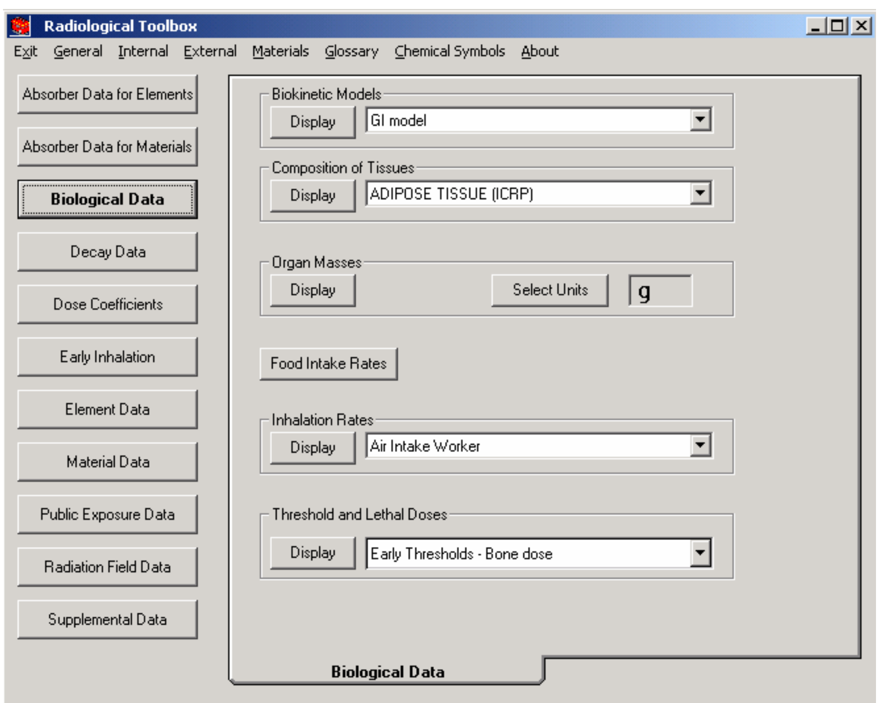

Fig. 4. The screen display for entrance into the biological data.

2.3 Decay Data

The Decay Data section (see Fig. 5) of the toolbox provides detailed data on the energy and intensities of the various radiations emitted during nuclear transformations. Differential energy spectra are included for beta emitting radionuclides and information on yield of radioactive decay products (daughters) in the decay chain. Two sets of data are included: one set being that of ICRP Publication 38 (ICRP 1983) and the second was derived from a compilation by the Japan Atomic

Energy Research Institute (JAERI) (Endo et al, 1999; Endo and Yamaguchi, 2001). The data are in the format of the file structure of Eckerman et al (1993).

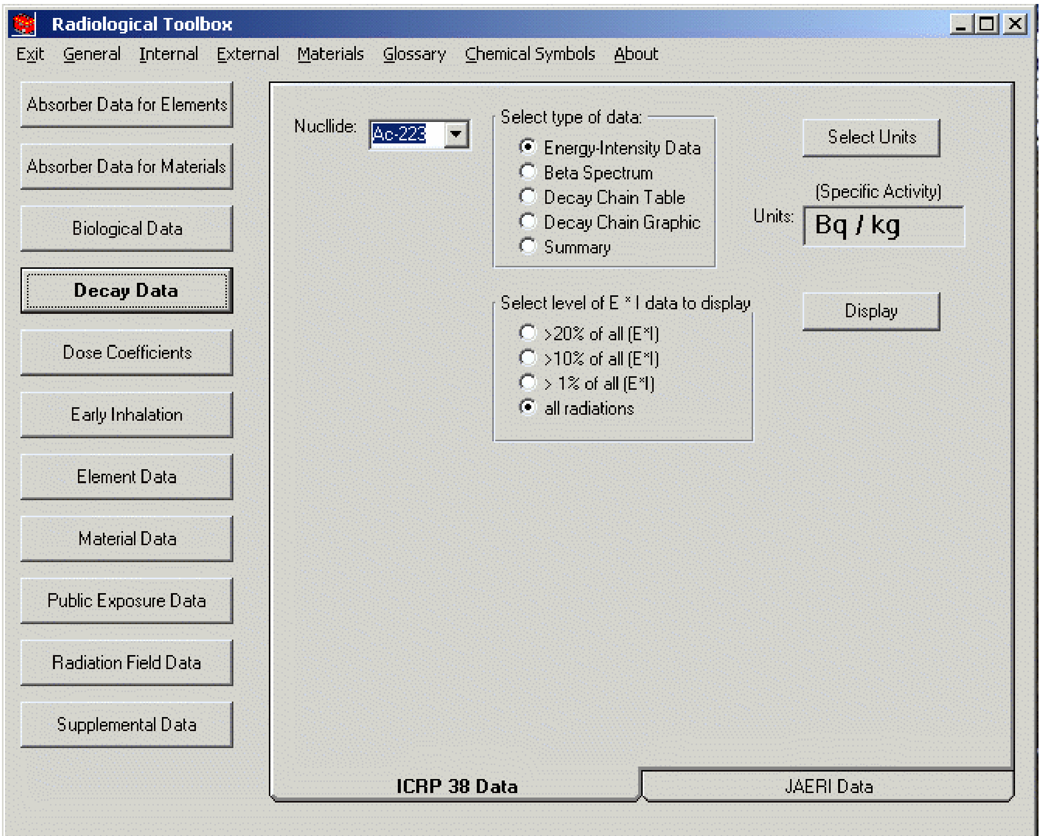

Fig. 5. The screen display for entrance into the decay data.

Information on the energy and intensity of the emitted radiations are displayed in separate tables for alpha particles, beta transitions (average energy), photons, and mono-energetic electrons. The type of radiation is identified in each table and its associated code, the variable *ICODE* – as defined by Eckerman et al (1993), is displayed. The beta table contains information on both beta + and beta – transitions, however the tabulated spectra is a composite over all beta transitions. X rays, gamma rays, and annihilation quanta are included in the photon table with their assigned *ICODE*. The data for internal conversion and Auger electrons are included in the monoenergetic electron table. The caption of each table lists the total number of that type of radiation emitted in the decay processes. In all tables the data are sorted by increasing energy. The tables include all the radiations without regard to the potential significance. It is possible to specify a fractional energy cutoff in percent thus limiting the tables to those radiations which contribution more that the cutoff to the total emitted energy of that type. For example, a cutoff of 1% would result in the table only containing radiations contributing more that 1% to the total energy for that radiation type. It is possible to sort the data by increasing intensity (yield) or by energy (the default sort variable). Each table may be separately exported to Excel. (That is, when you press Export only the radiations in the table being displayed are exported.)

The beta spectrum is displayed as a graph, but the differential spectrum, the number of electrons emitted with energy between E and $E+dE$ - $Y(E)\,dE$, as a function of energy E, is exported as a table.

The decay chain table includes the specific activity, half-life, decay mode, and identification of radioactive daughters with their and branching fractions. The default units for specific activity are Bq/kg. You may change these units. This table can not be exported.

Decay chain graphics include half-lives and branching fractions. The stable end-product of the chain is included – it is not included in the decay chain table. The graphic can not be exported.

The decay data summary contains half life, decay mode, specific activity, total emitted energy, gamma constant, and a summary table of the four radiation types.

2.4 Dose Coefficients

The Dose Coefficients section (see Fig. 6) of the toolbox provides access to five sets of nuclide-specific dose coefficients. They are: external dose rate coefficients for 826 radionuclides from Federal Guidance Report 12 (EPA, 1993), the committed dose coefficients for the inhalation and ingestion of 738 radionuclides from ICRP Publications 30 and 68 (ICRP 1978, 1994), and age-dependent committed dose coefficients for the inhalation and ingestion intakes of 738 radionuclides by members of the public (six ages at intake) from ICRP 72 (ICRP, 1983). From each set of coefficients it is possible to display up to 20 nuclides at a time for a chosen route of exposure or intake. The data in the display can be exported to an Excel spreadsheet. The default units used are SI; i.e., units of the original data however the user may specify non SI units for display and export.

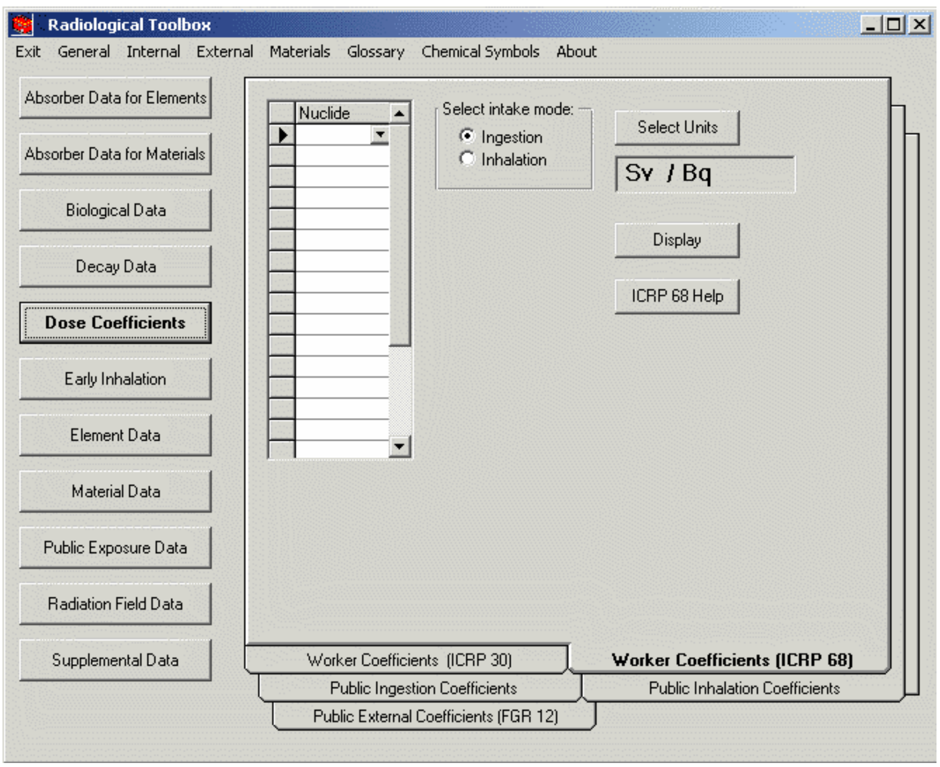

Fig. 6. The screen display for entrance into the dose coefficient data.

Coefficients are displayed for the organ (equivalent dose) and the effective dose for each radionuclide selected. For exposure to radionuclide contamination outside the body, the coefficients are for the adult as considered in Federal Guidance Report 12. For the internal data, dose coefficients are displayed for all particulate absorption Types (or clearance Class in the ICRP 30 data set), for gases and vapors, if applicable, and the f_1 (fractional absorption from GI tract) is shown for the selected radionuclide. The type or class, f_1, and half-life are included in the display and in any table export to Excel.

Note that both the set of nuclides selected for display and the selected units for the coefficients 'stick' across data sets by coefficient type. That is, once a set of nuclides or units have been selected for internal dose coefficients, these units will be applied to all internal coefficients selected while running the toolbox, until different units are specified.

2.5 Early Inhalation

The Early Inhalation section (see Fig. 7) of the toolbox provides access to the inhalation dose coefficients for early (deterministic) effects. These coefficients, in terms of absorbed dose – separate values given for low and high LET, are available for small intestine, red marrow, lung (mass average) and alveolar interstitial region only and are computed based on dosimetric data archived on the Federal Guidance Report 13 CD (Eckerman et al 1999). The user may specify integration times (up to 20 times) from 1 day to 10 years. The units of these coefficients may be changed. The coefficients may be exported to Excel.

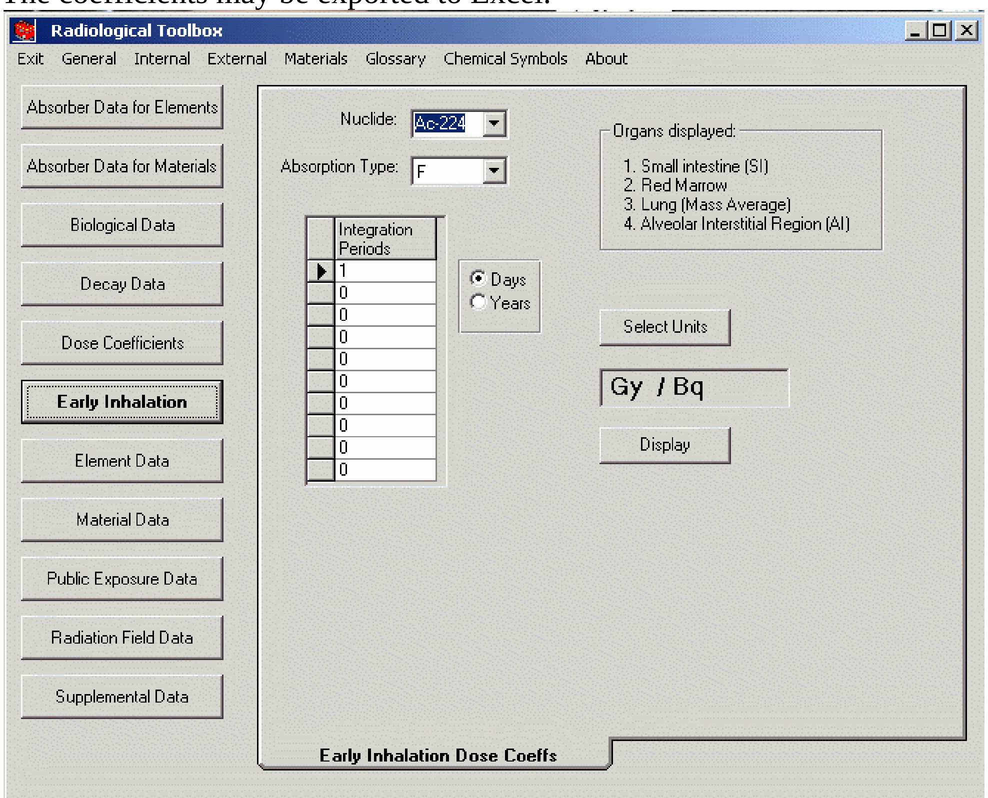

Fig. 7 The screen display for entrance into the absorbed dose coefficients for early effects.

2.6 Element Data

The Element Data section (see figure 8) provides access to atomic mass and isotopic abundance data. These data may be exported to Excel spreadsheets. These data are from Coursey et al. (2001).

Stable and primordial and cosmogenic radioactive isotopes are marked with a colored background. These data were abstracted from 16th edition of the Chart of the Nuclides (Baum et al 2002).

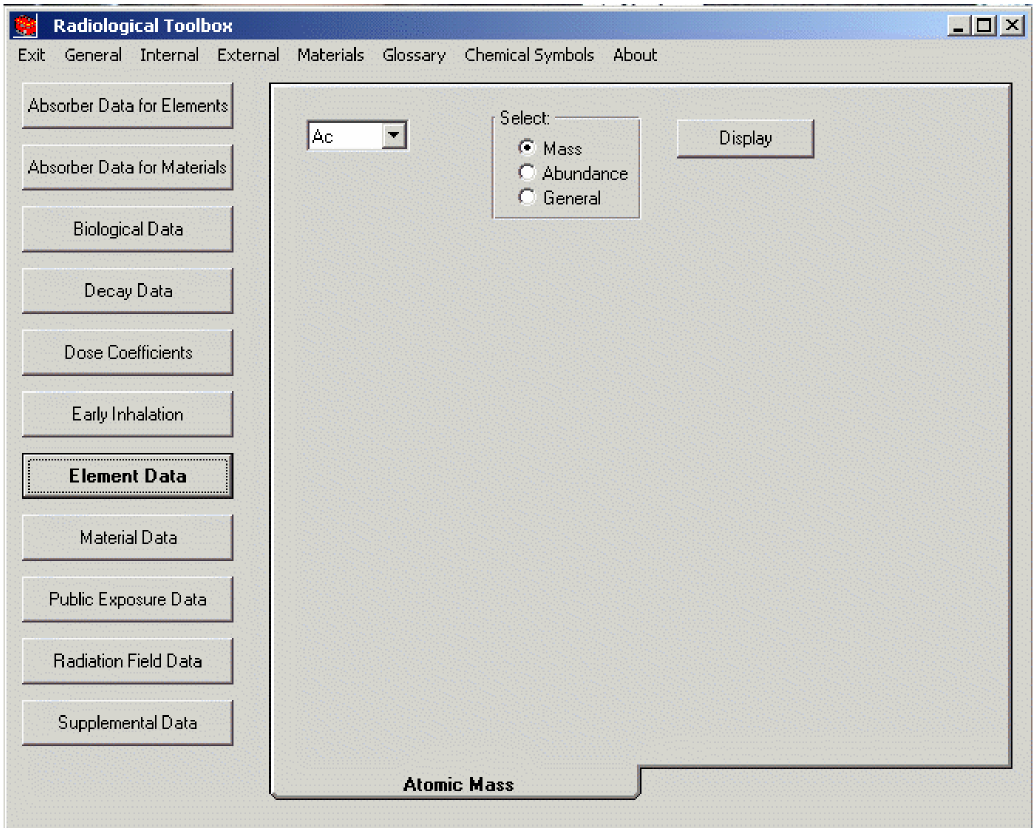

Fig. 8. The screen display for entrance into the element data section.

2.7 Material Data

The Material Data section (see Fig. 9) provides you with access to composition data for selected materials. The composition data are displayed as atomic fraction. This table may be sorted by atomic number or fraction. These data may be exported to Excel spreadsheets. These data are from Coursey et al. (2001).

2.8 Public Exposure Data

The Public Exposure Data section (see Fig. 10) contains data such as:

- natural background radiation
- background radiation in the body
- concentrations of radionuclides in materials
- concentrations of radionuclides in devices
- concentrations of primordial radionuclides
- typical exposures during medical procedures

The natural background radiation and background radiation in the body are from NCRP94 (1988). The concentrations of radionuclides in materials are from S. Schneider, et al. (2001). The concentrations of radionuclides in materials and of primordial radionuclides are from the Radiation Information Network (ISU, 2003). The typical exposures during medical procedures are from RTM-96 (NRC, 1996).

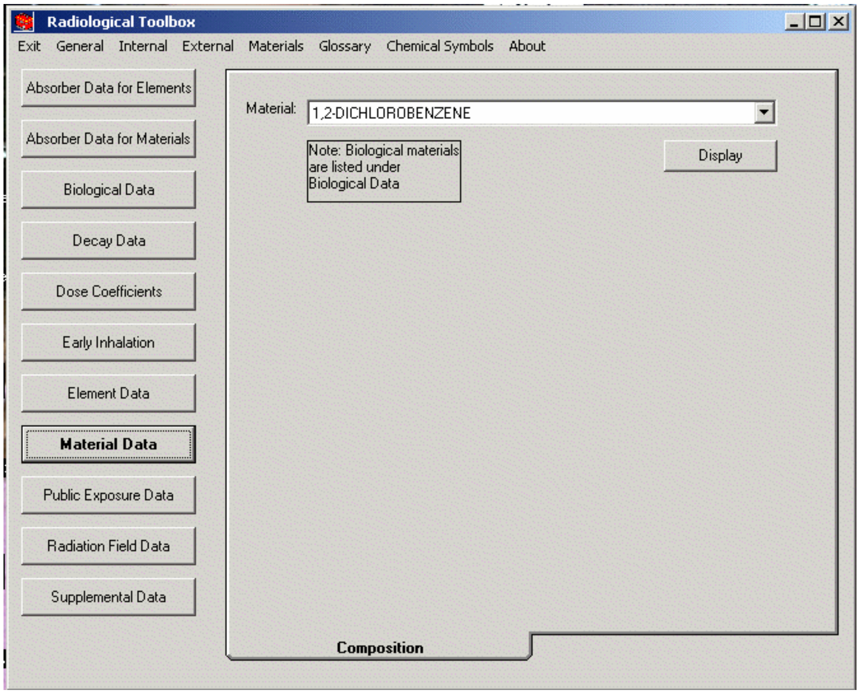

Fig 9. The entrance to the material data.

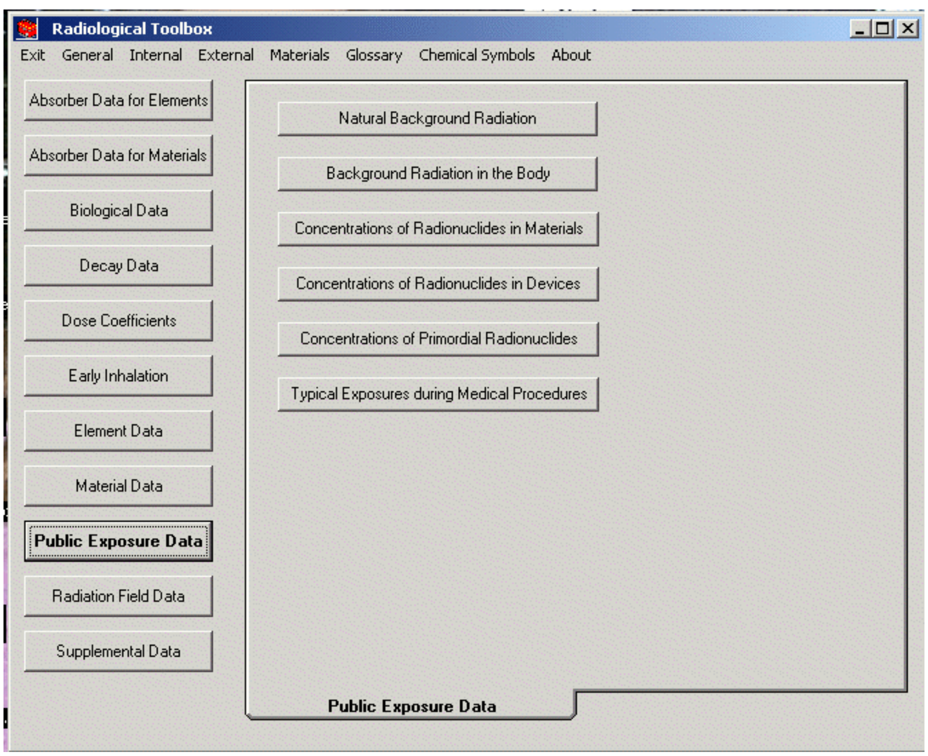

Fig 10. The entrance to the public exposure data.

2.9 Radiation Field Data

The Radiation Field Data section (see Fig. 11) provides access to conversion coefficients for the operational quantities and organ dose coefficients for neutron and photon radiation fields. These data were compiled by a joint task group of the ICRP and the ICRU and were abstracted from ICRP Publication 74 (ICRP, 1977b). In addition to operational coefficients, organ dose coefficients are available for six geometries: antero-posterier, postero-anterier, left-lateral, right-lateral, rotational and isotropic. Graphics of these geometries are displayed. Once the table is displayed, you may plot any column in the table by double-clicking on that data. The entire table may be exported to Excel

2.10 Supplemental Data

The Supplemental Data section (see Fig. 12) provides you with access to other radiation and health-physics data. This section is fully implemented. However, we intend to add additional information to each existing category. This section includes:

- SI Units
- Physical constants
- Conversion factors
- Equations
- Web links

The physical constants and conversion factors may be exported to the clipboard by right-clicking on the value. A simple web browser is available to view the web links. The SI units are from Baum etl al (2002). The physical constants and conversion factors are from Lide (1997). The equations are from various sources.

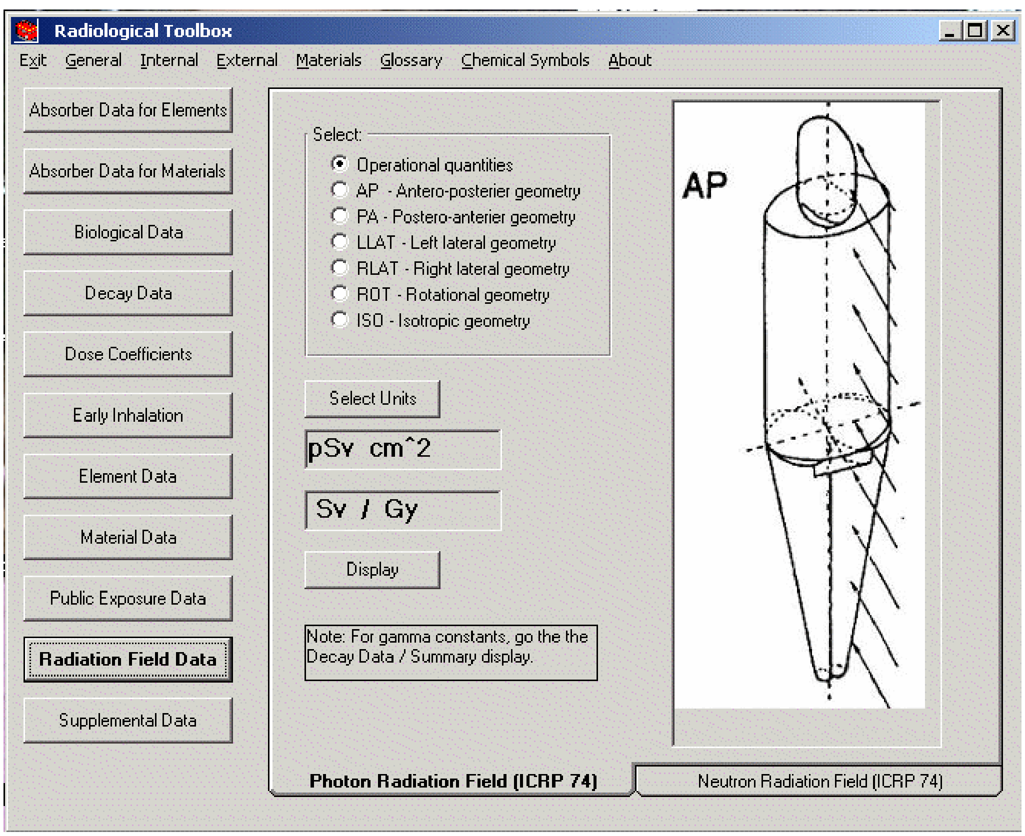

Fig. 11. The entrance to the conversion coefficients for radiation fields.

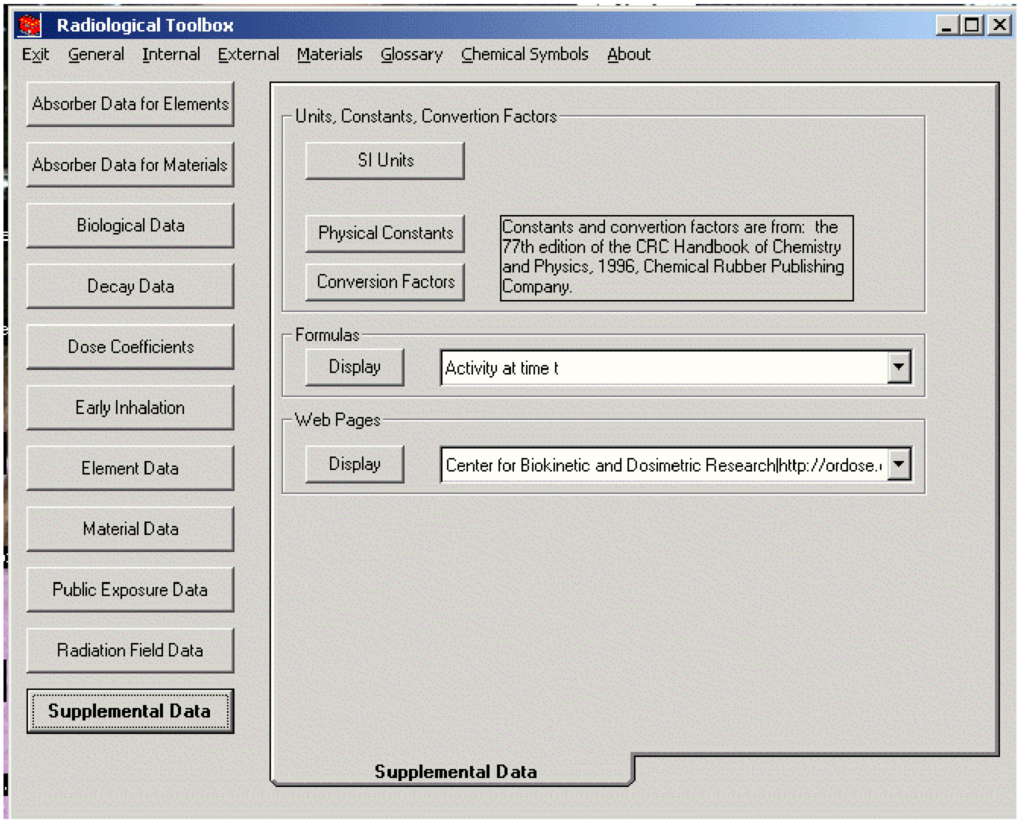

Fig. 12. The entrance to the supplemental data.

3.0 HOW TO …

This section describes the use of some of the Rad Toolbox features.

3.1 How to Use the Dose Coefficient Nuclide Input Grid

Dose coefficients can be requested for up to 20 radionuclides in a single query. You may either type in the radionuclide name or select it from the choice list. Once the choice list is selected, you can navigate the list by typing the first few characters of the selected name. If you type in an invalid name (either from miss-spelling or from trying to access a radionuclide that is not present in that database), you will be shown an error message and you will not be able to leave that cell until you correct the mistake or blank the cell. You should always enter a name in the top cell of the list, but there may be blanks in between other entries. The table displayed will not necessarily have the radionuclides in the order that you entered the names.

3.2 How to Use the Nuclide, Element, Material Choice Lists

For the choice lists where you select a single value, you may either type in the item name or select it from the choice list. Once the choice list is selected, you can navigate the list by typing the first few characters of the selected name. If you type in an invalid name (either from miss-spelling or from trying to access an item that is not present in that database), you will be shown an error message and you will not be able to leave the cell until you enter or select a valid name.

3.3 How to Export Data

If you do not have Excel on your PC, you cannot export data from the Rad Toolbox. Export buttons are available on each table that may be exported. The first time that you press Export, a new Excel file is opened. The data in the table you are viewing are copied to the first sheet of that file. If you leave that Excel file open and export additional data, those data will be copied to the same sheet as the previous exported data. The will be positioned next to the previous data, with one blank column in between. If you close the Excel file, a new file will be opened when you next export. The Rad Toolbox will not export data to an existing file.

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The authors would like to acknowledge the following direct and indirect contributors to this work.

The International Commission on Radiological Protection (ICRP) for granting permission to extract the inhalation and ingestion dose coefficients from its CD entitled “The ICRP Database of Dose Coefficients: Worker and Members of the Public.” This CD should be consulted for further details regarding dose coefficients. For example, the ICRP CD contains coefficients for aerosols of sizes other than the default sizes presented here.

The external dose coefficients, nuclear decay data, and dose coefficients for deterministic effects were assembled at ORNL under the sponsorship of the U.S. Environmental Protection Agency during the preparation of Federal Guidance Report 13.

The alpha, electron, and photon interaction coefficients were adapted from publications and codes of the National Institute of Science and Technology (NIST). In addition the elemental composition of various materials was abstracted from these publications. These data underlie many reports of the International Commission on Radiation Units and Measurements (ICRU).

The nuclear decay data denoted as ‘JAERI Data’ were assembled from the publications and data files developed at the Japan Atomic Energy Research Institute. We gratefully acknowledge the assistance of A. Endo of JAERI.

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